Three-Component Velocity Measurements in the Wake of a Rotor in Hover

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Improved rotorcraft aeroacoustic and performance analyses are highly dependent on the accurate modeling of the rotor wake structure, in particular, the strength and size of the blade-tip vortex. Particle image velocimetry (PIV) can provide these structural wake measurements very efficiently. The present investigation represents the first three-component PIV measurements acquired in a rotor wake by NASA.

The objective was to acquire three-component velocity fields in the wake of a hovering, two-bladed, untwisted rotor and determine the vortex size and strength as a function of wake age. A 7.5-foot-diameter rotor with a constant chord of 7.5 inches was selected for the study. The rotor was operated at a tip speed of 342 feet per second with the rotor thrusting downward (wake up) to minimize recirculation; 500 PIV stereo image pairs were acquired for each wake age, which ranged from 0 to 270 degrees.

Figure 1 shows an *instantaneous* in-plane velocity field with associated contours of vorticity. The vorticity map clearly identifies the location of the vortices shed from the rotor blade tip. The wake age of the vortex in the lower left corner is approximately 30 degrees. The upper vortex was generated by the preceding blade and has a wake age of approximately 210 degrees. For clarity, only alternate rows and columns of velocity vectors are shown (1/4 the total number of vectors). Figure 2 shows the *same* instantaneous in-plane velocity field with associated contours of out-of-plane velocity. The out-of-plane velocity map helps identify the wake trailed from the inboard part of the blade. The direction of positive out-of-plane velocity is out of the paper. This is also the direction of blade motion.

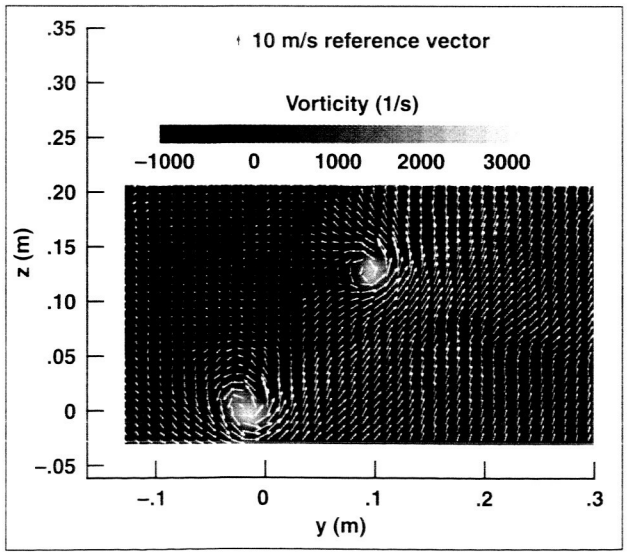

Fig. 1. Instantaneous in-plane velocity field with vorticity map.

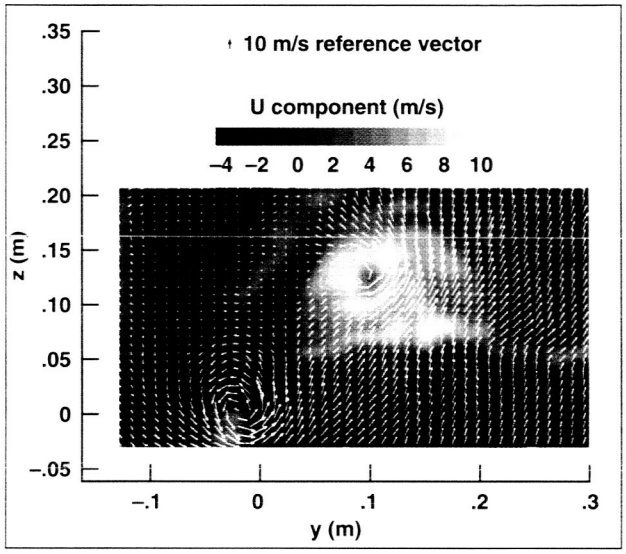

Fig.2. Instantaneous in-plane velocity field without vorticity map.

Vortex-wander effects necessarily contaminate measurements of vortex wakes that rely on point measurement techniques. Whole flow-field techniques like PIV allow us to mitigate such effects by averaging in a coordinate system fixed with respect to the vortex. Such an average retains the vortex structure despite vortex wander and provides a better estimate for the mean vortex structure.

These results clearly demonstrate the feasibility of using three-component PIV for rotor wake measurements in hover, and this technique will be extended to the study of rotors in forward flight.

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